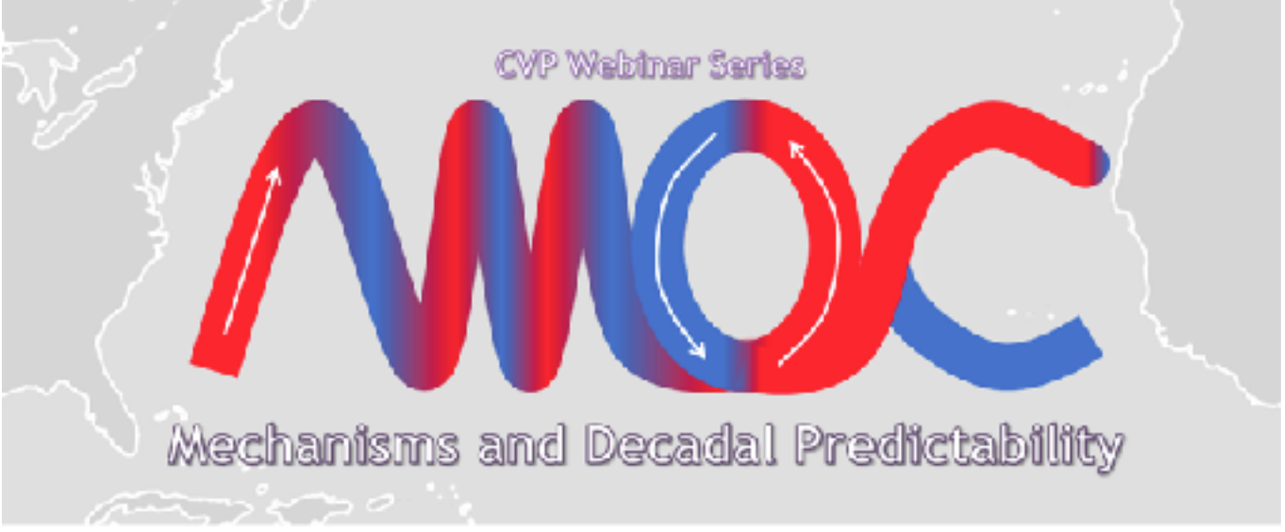



Oregon State UNIVERSITY OSU College of Earth, Ocean, and Atmospheric Sciences

# Modeling Effects of Greenland Ice sheet Melting on AMOC Variability and Predictability

Andreas Schmittner, Pepijn Bakker[1], and many more

[1]now at MARUM, University of Bremen, Germany

Funded by NOAA's CVP program

NOAA CLIMATE PROGRAM OFFICE
Advancing scientific understanding of climate, improving society's ability to plan and respond

Climate Variability and Predictability Webinar Series, Nov. 9, 2016

# Motivation

- Scientific and public (mis-)conceptions of Greenland Ice Sheet (GrIS) melt effects on AMOC

- Previous assessments (e.g. IPCC) use model projections without GrIS melting

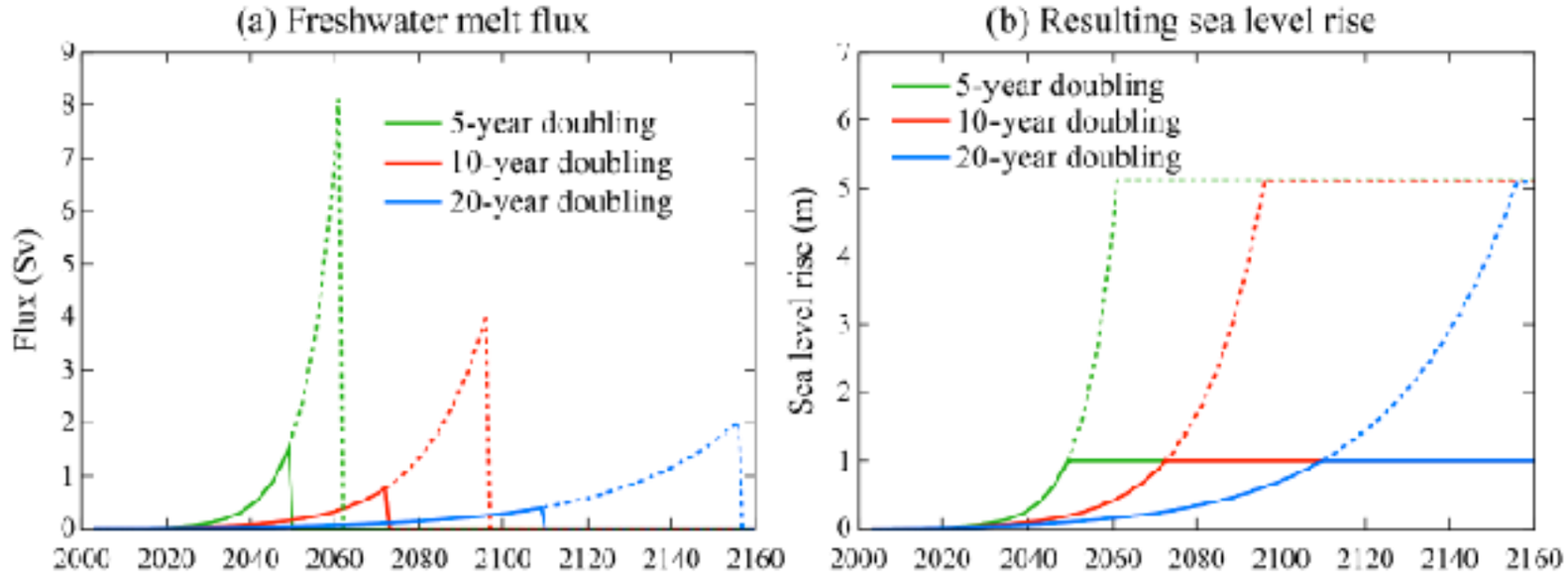
- **Goals**: Include GrIS melting in the most realistic way possible and produce multi-centennial, probabilistic AMOC projections

Atmos. Chem. Phys., 16, 3761–3812, 2016
www.atmos-chem-phys.net/16/3761/2016/
doi:10.5194/acp-16-3761-2016


Atmospheric Chemistry and Physics
Open Access
EGU

# Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming could be dangerous

James Hansen[1], Makiko Sato[1], Paul Hearty[2], Reto Ruedy[3,4], Maxwell Kelley[3,4], Valerie Masson-Delmotte[5], Gary Russell[4], George Tselioudis[4], Junji Cao[6], Eric Rignot[7,8], Isabella Velicogna[7,8], Blair Tormey[9], Bailey Donovan[10], Evgeniya Kandiano[11], Karina von Schuckmann[12], Pushker Kharecha[1,4], Allegra N. Legrande[4], Michael Bauer[4,13], and Kwok-Wai Lo[3,4]






SCIENCE

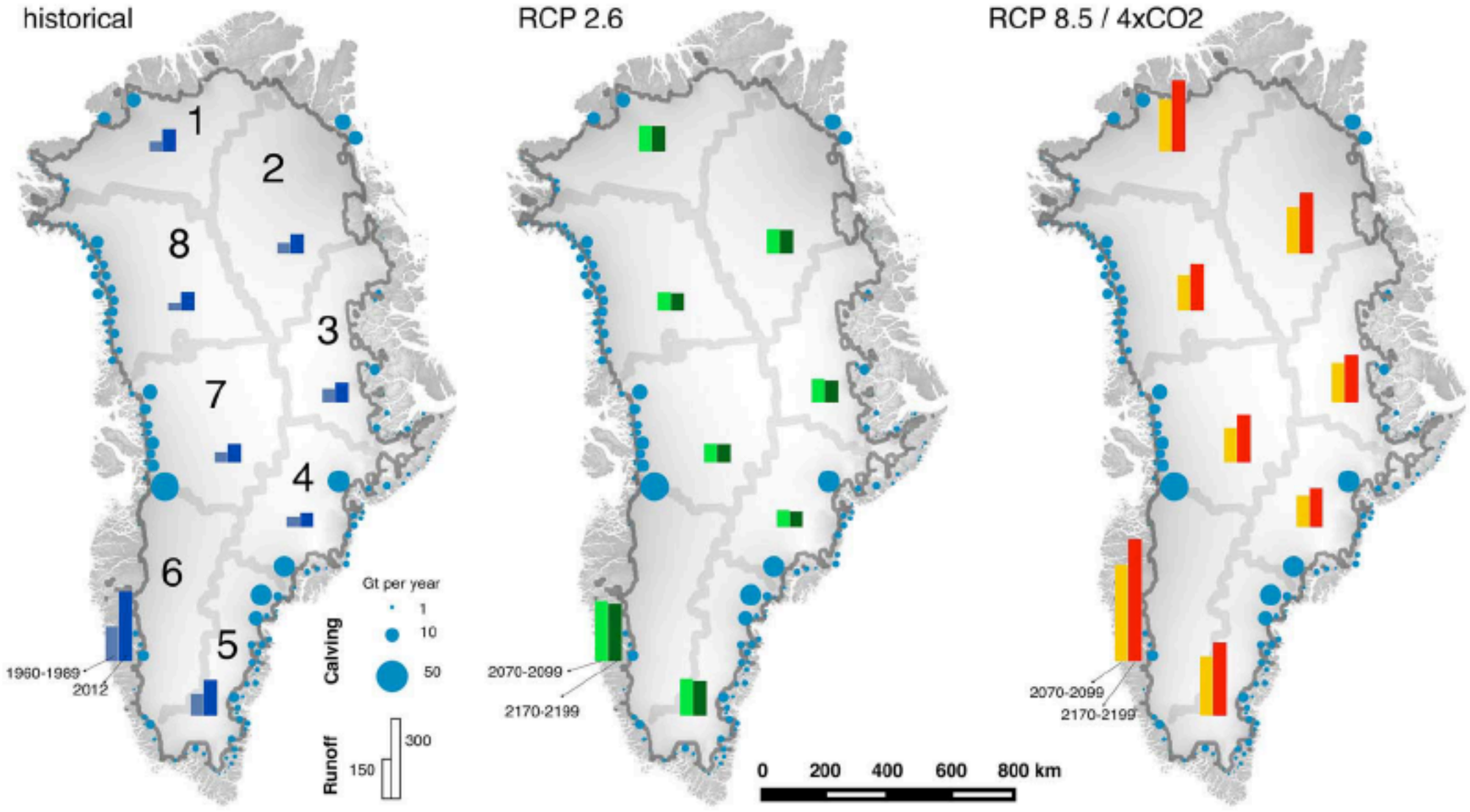
## *Scientists Warn of Perilous Climate Shift Within Decades, Not Centuries*

By JUSTIN GILLIS MARCH 22, 2016

# AMOCMIP

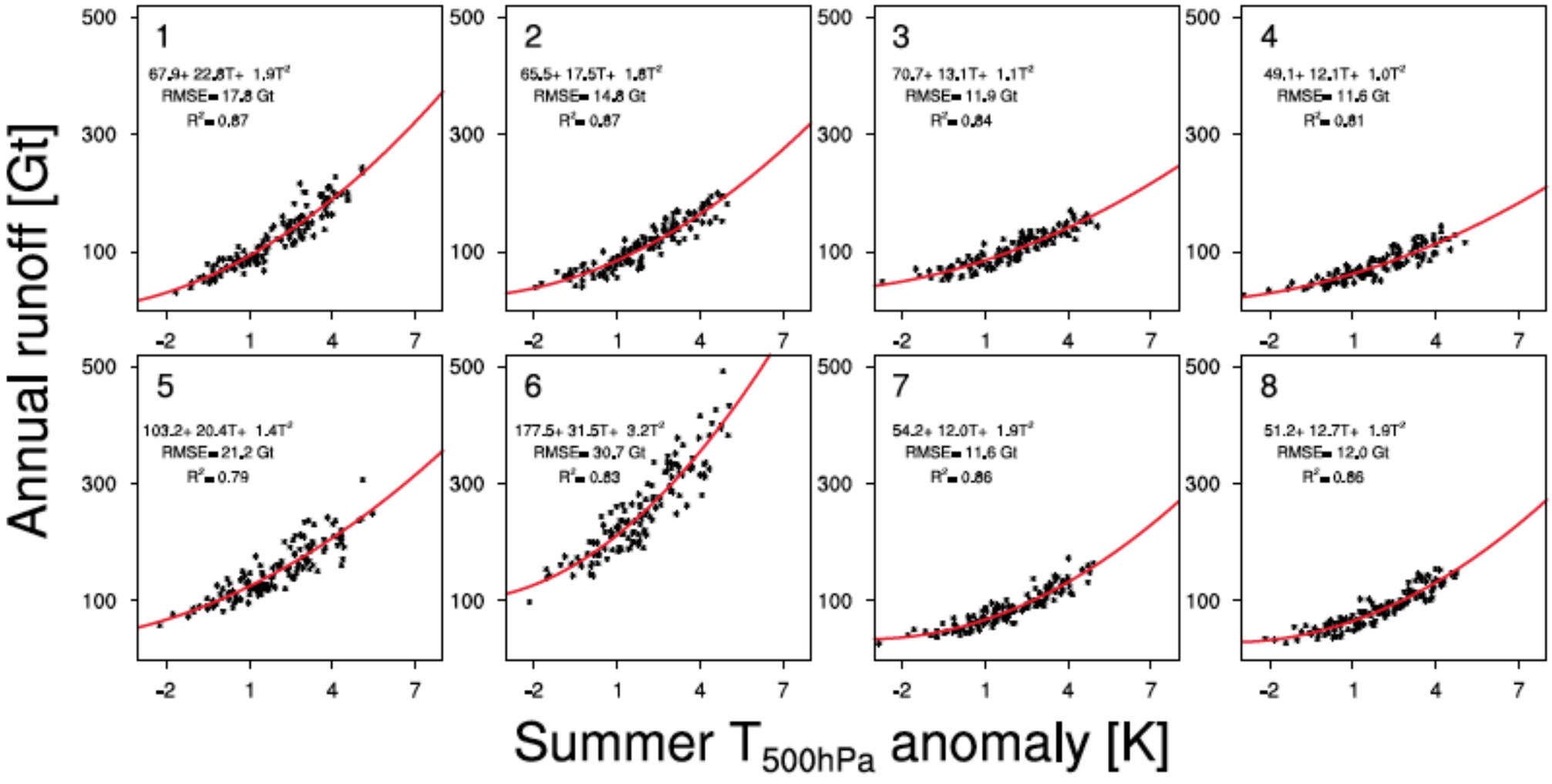
- Model Inter-comparison Project assessing effect of warming and GrIS melting on AMOC
- Use realistic GrIS melt rates and distributions
- 8 international modeling groups

# GrIS meltwater fluxes calculated in 8 drainage basins …



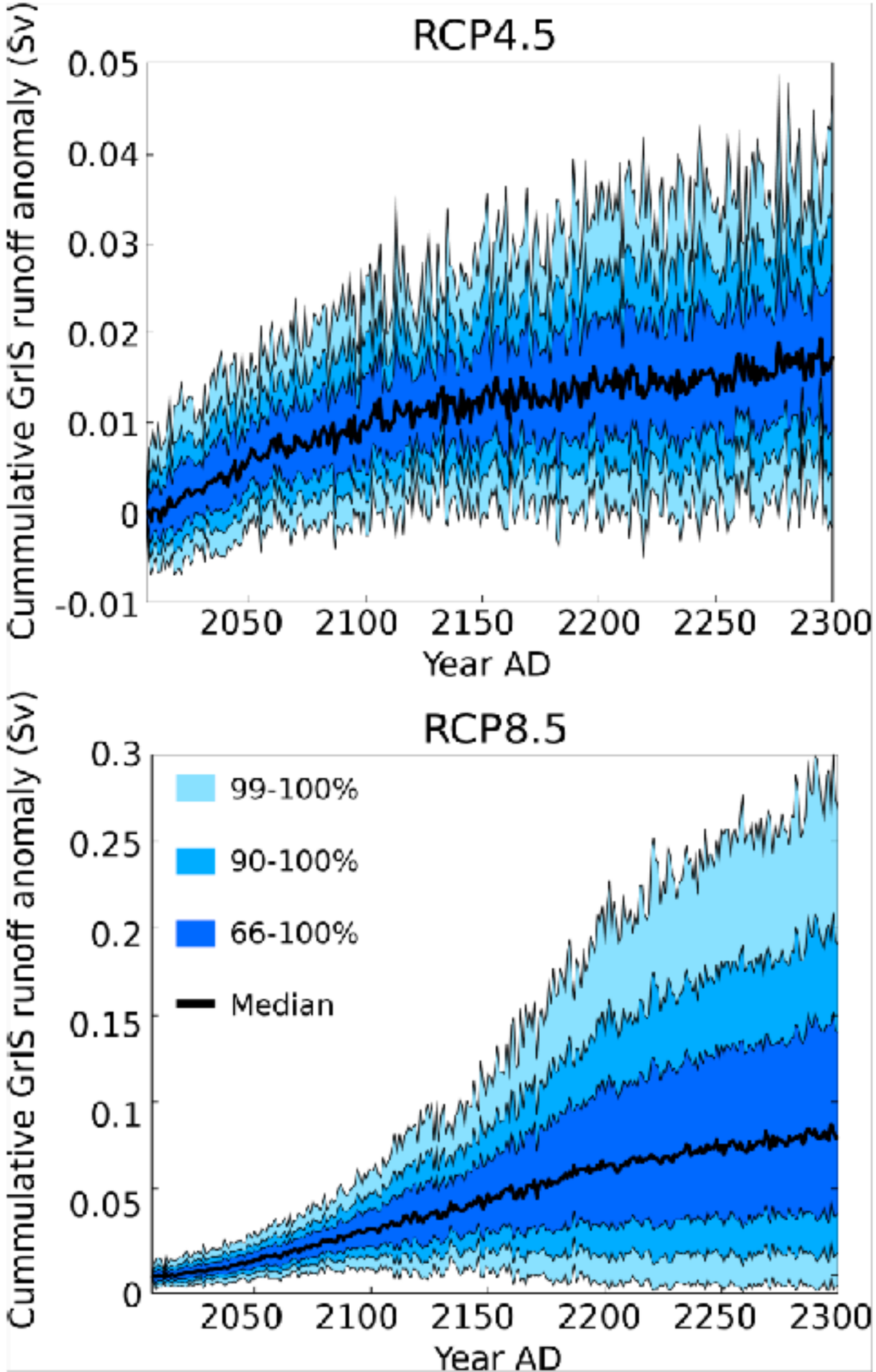

Lenaerts et al. (2015)

# … based on mid-tropospheric air temperature relationships from high-res, regional climate model (RACMO2)



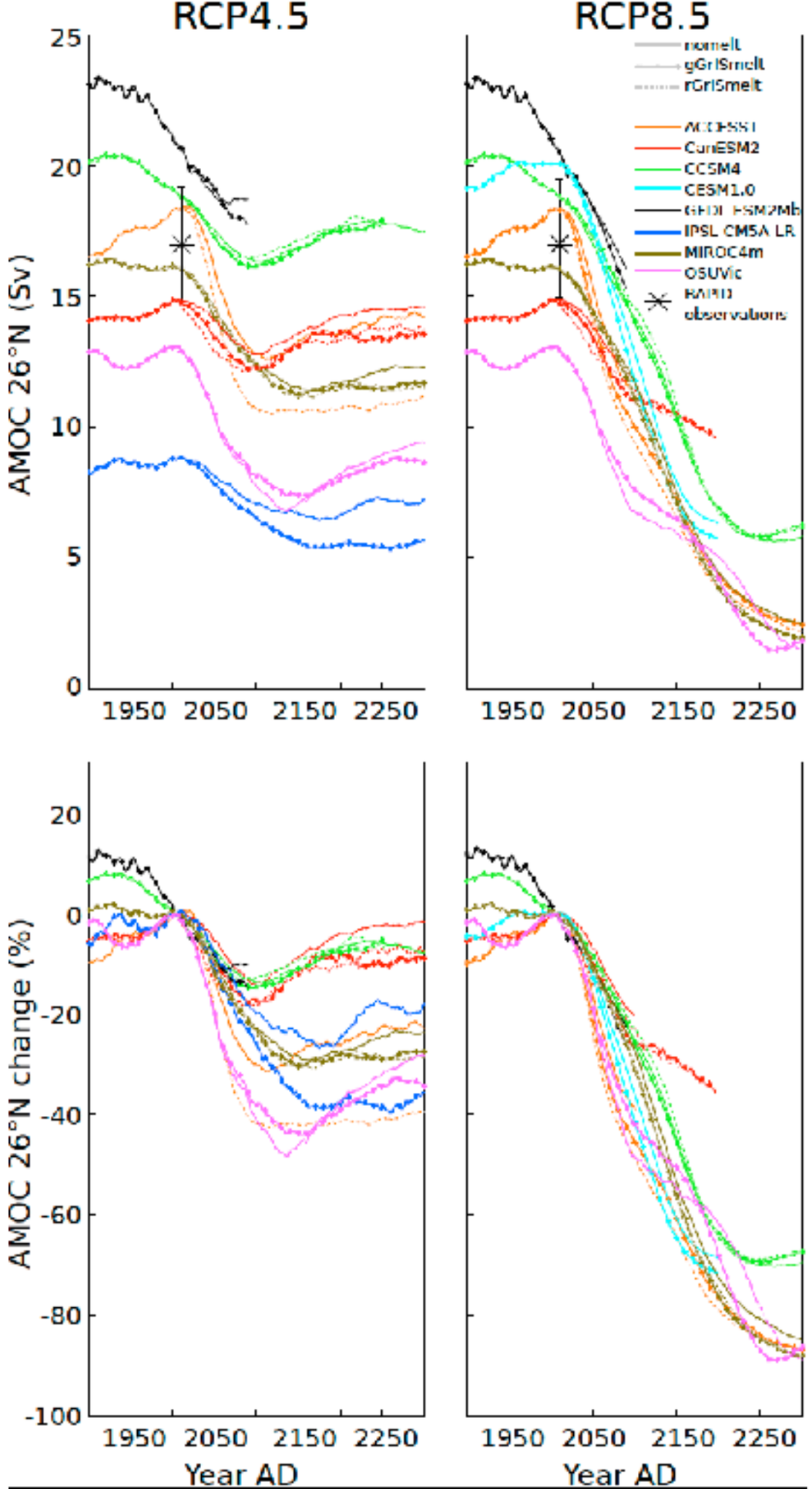

CMIP5 Multi-Model-Mean $T_{500hPa}$

Lenaerts et al. (2015)




# GrIS freshwater forcing (surface melt only)

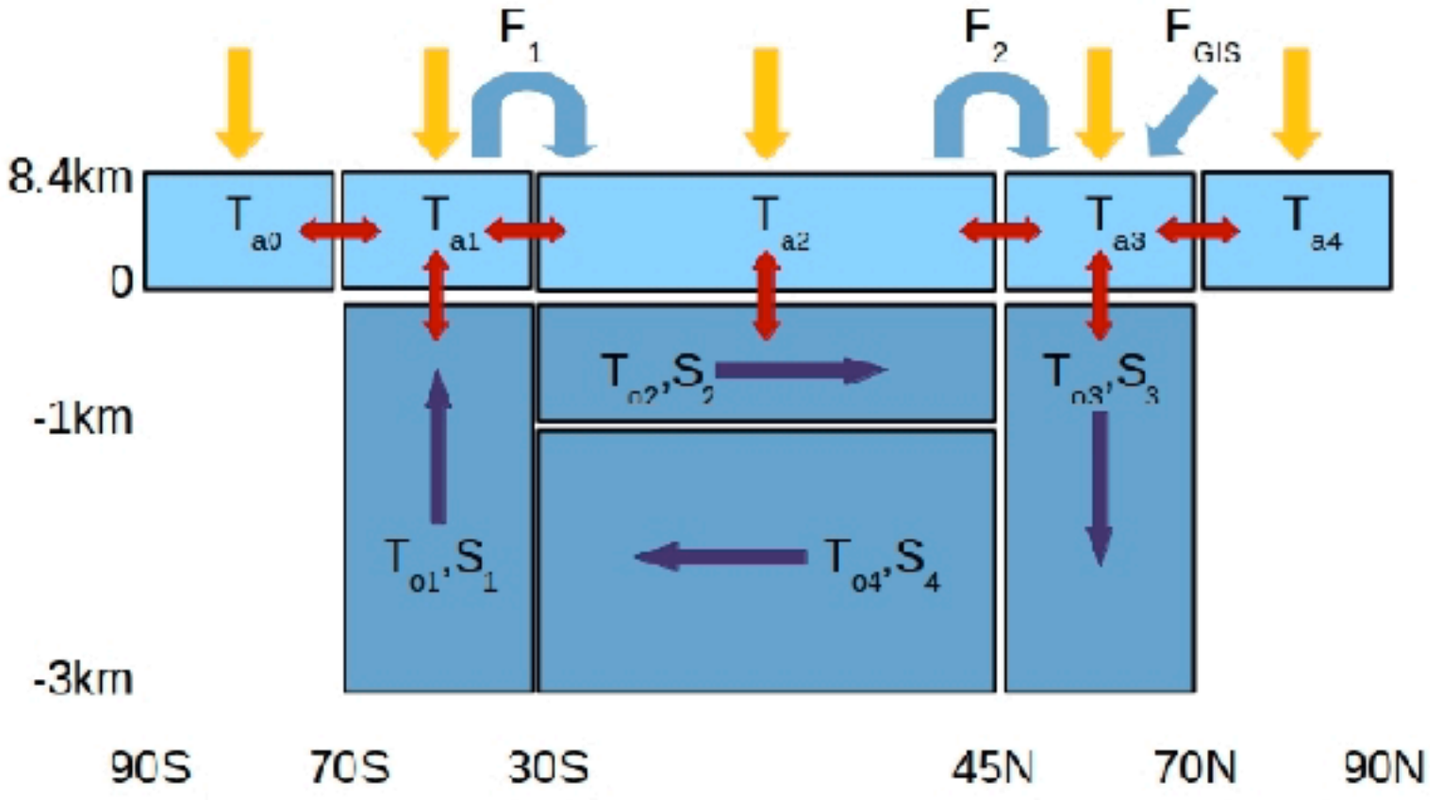
- from CMIP5 ensemble (uncertainty used in probabilistic projections shown later)
- calving changes not included
- RCP4.5: 0-0.015 Sv
- RCP8.5: 0-0.1 Sv
- much less than assumed by Hansen et al. (2016; 1-4 Sv)
- added to two ‘baselines’:
  - GCM (gGrISmelt)
  - RCM + obs calving (rGrISmelt)

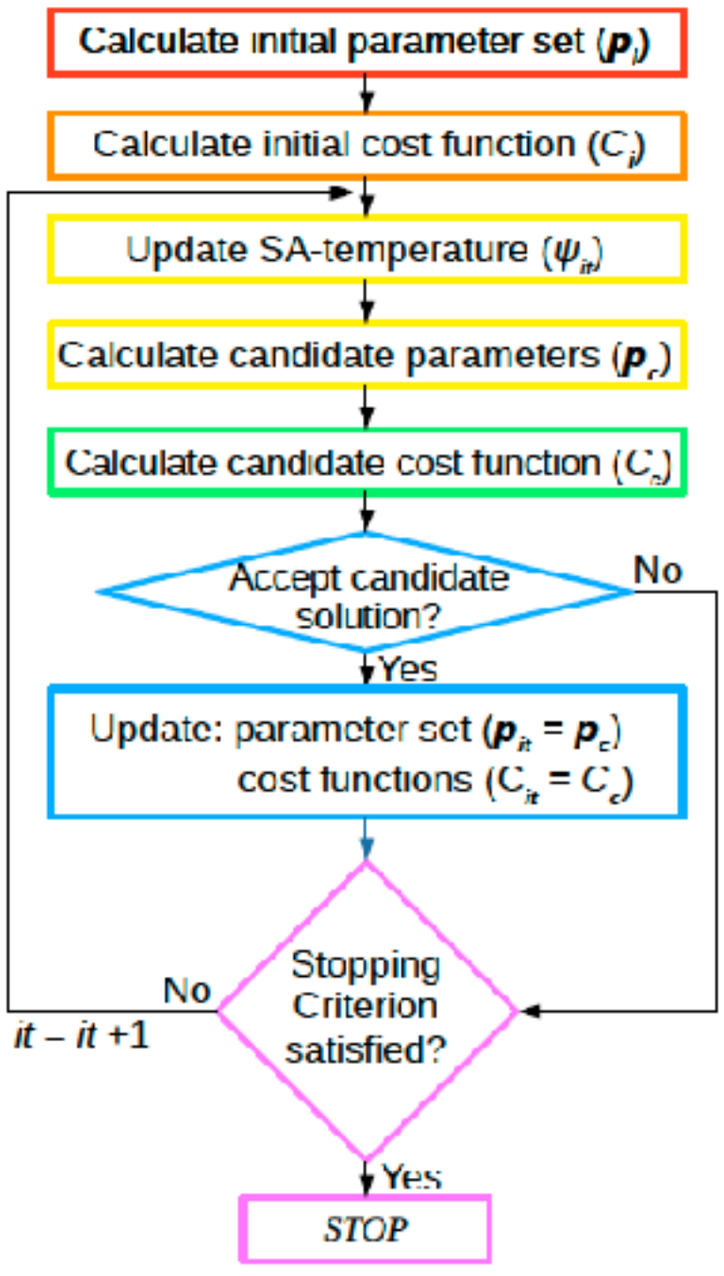



# AMOCMIP Results

- RCP4.5: AMOC slowdown until 2100, then stabilization / recovery
- RCP8.5: continued and large slowdown until 2300
- GrIS effects AMOC
- Additional reduction in RCP4.5
- Not much effect in RCP8.5

# Box model emulator used for probabilistic projections



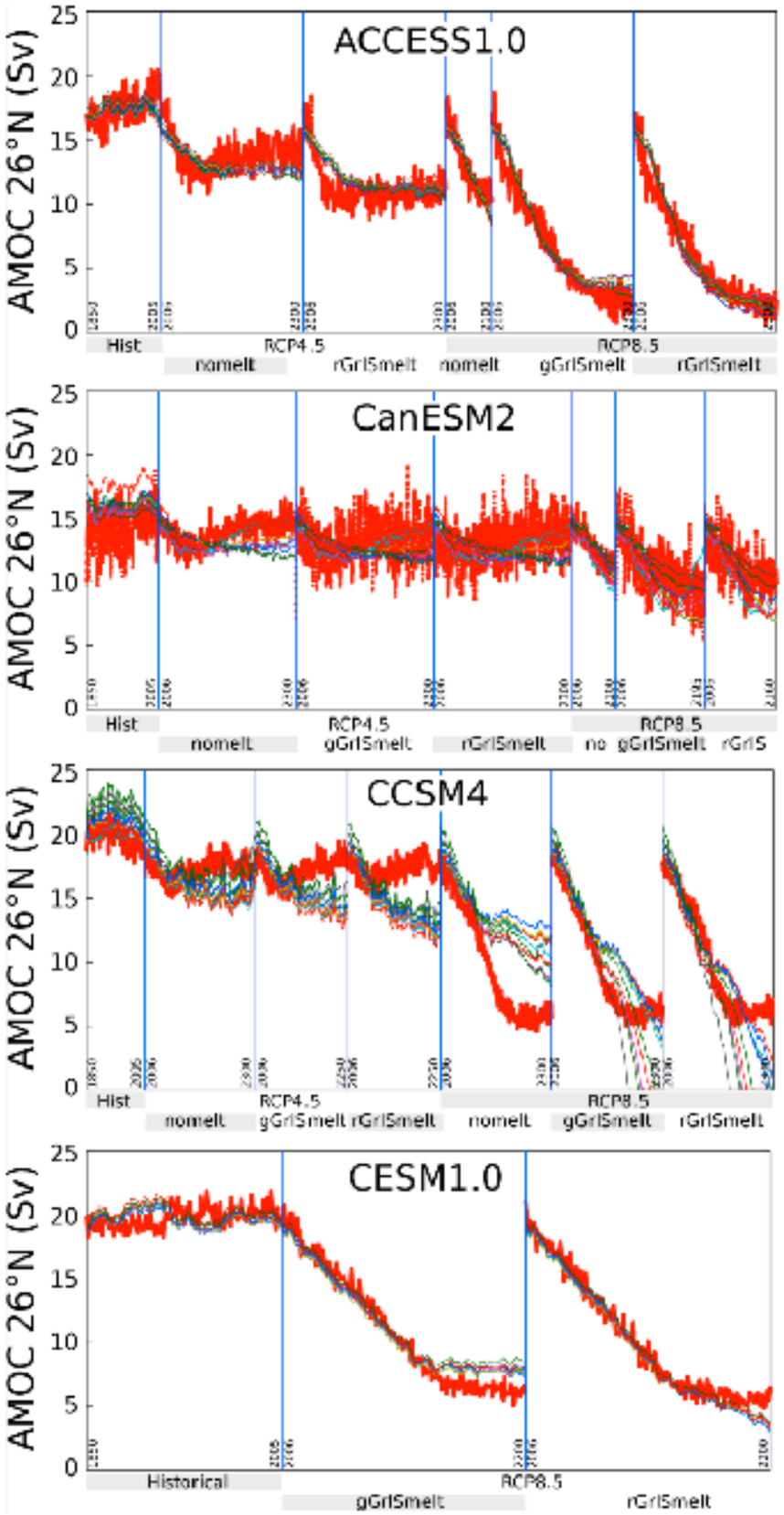




based on previous work by Stommel, Rahmstorf, Zickfeld

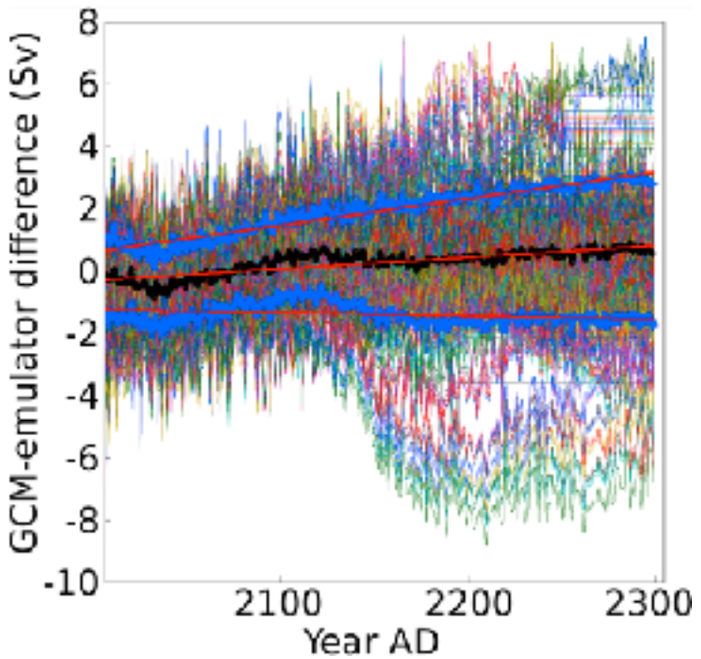
# Uncertainties Included

- Greenhouse gas concentration changes
- Climate sensitivity including regional temperature changes (e.g. polar amplification, spatial correlations considered)
- GrIS mass loss
- AMOC sensitivity to climate and GrIS

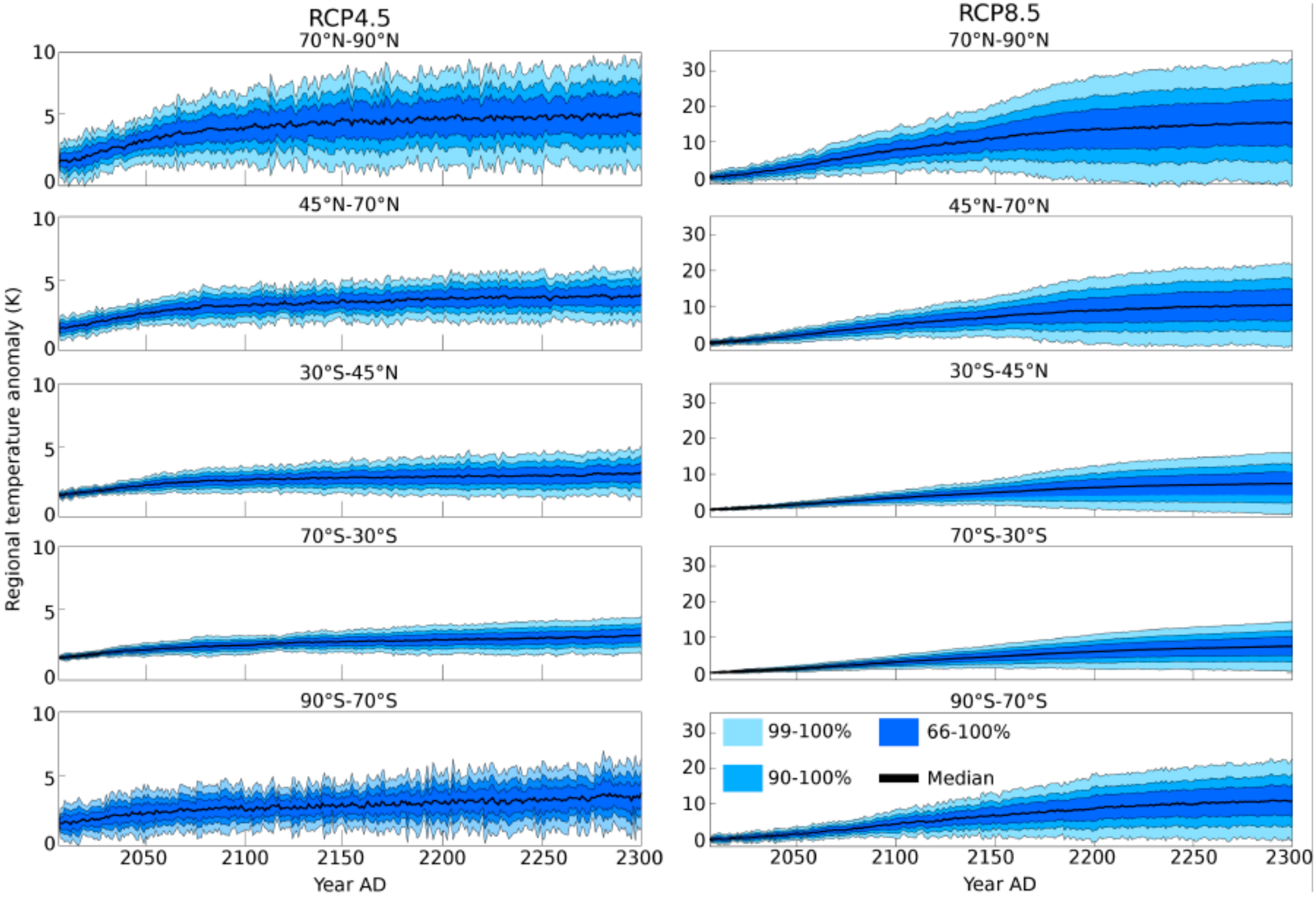
# Emulator fit to GCMs

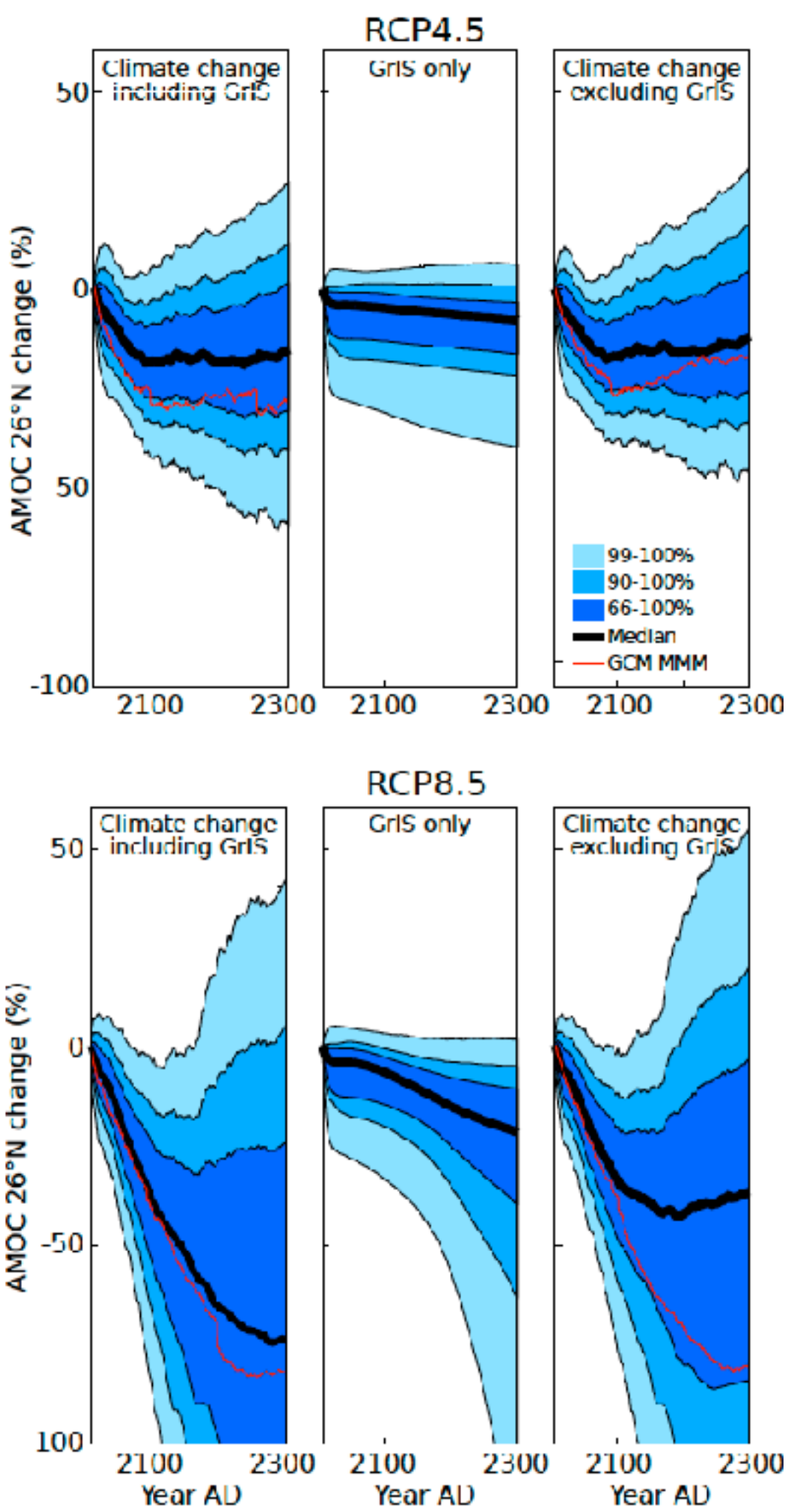



- red: GCM
- thin lines: Emulator
- Emulator fits most GCMs & scenarios well
- error = 1-2 Sv (considered in uncertainty estimate)



# Regional temperature forcing from CMIP5

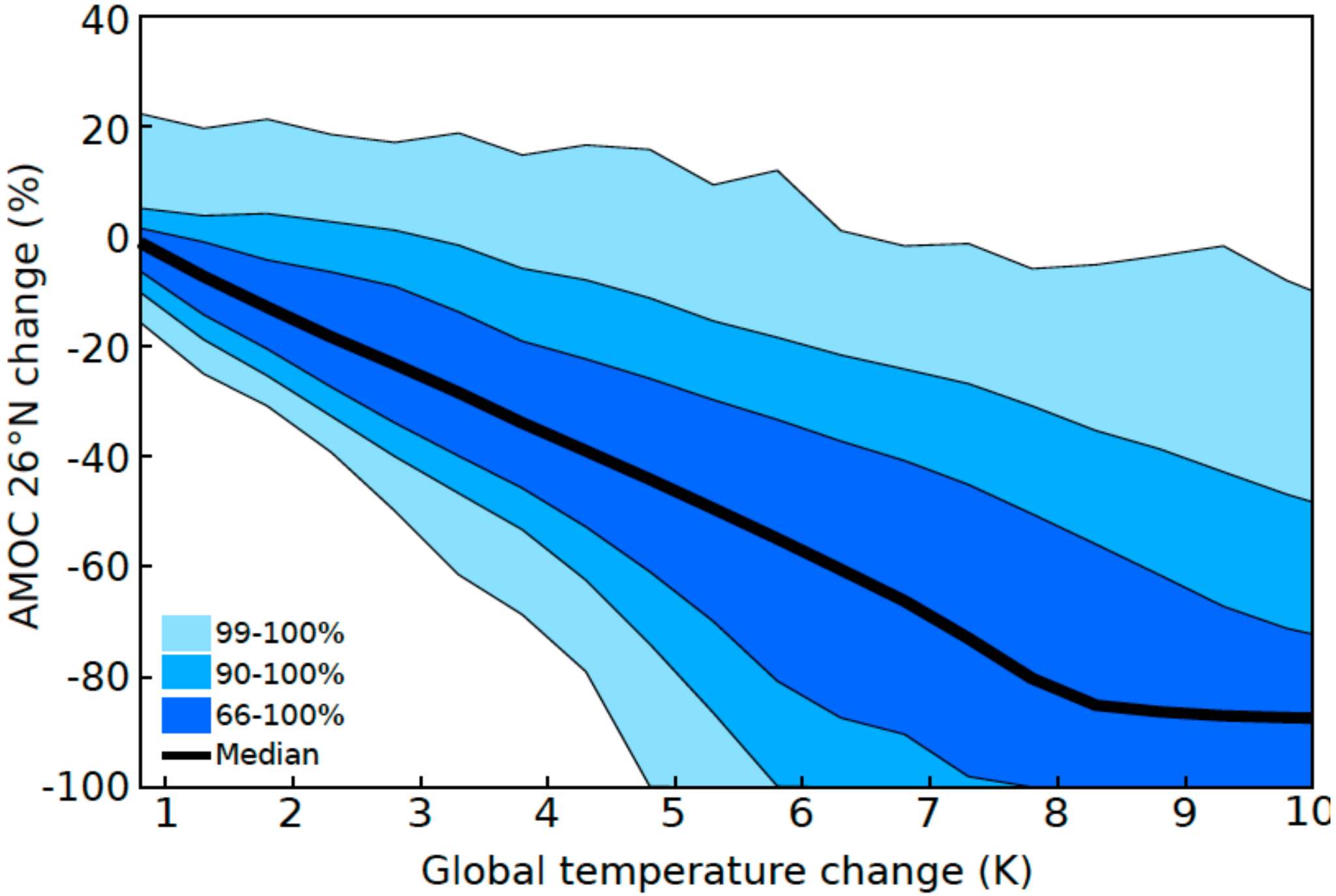





# Probabilistic Projections Results

- RCP4.5: AMOC slowdown until 2100, then stabilization; zero collapse probability
- RCP8.5: continued and large slowdown until 2300; significant collapse probabilities after 2100
- GrIS effects AMOC
- Small additional reduction in RCP4.5
- Larger effects in RCP8.5 include increased collapse probabilities

# Probabilistic Projections Results



# Conclusions

- AMOC response depends strongly on forcing
  - RCP4.5 reduction, stabilization
  - RCP8.5 no stabilization, significant collapse probability
- GrIS effects significant but not dominant

Bakker et al. (in review) Fate of Atlantic Meridional Overturning Circulation — Strong decline under continued warming and Greenland melting, Geophysical Research Letters

# Future Work

- Consider freshwater fluxes from Antarctica
- Explore different emulators
- Extend projections beyond 2300
- Assess impacts (e.g. on ecosystems, biogeochemistry, carbon cycle)

# Thanks

Encore: calving effects

Upcoming Nature paper:

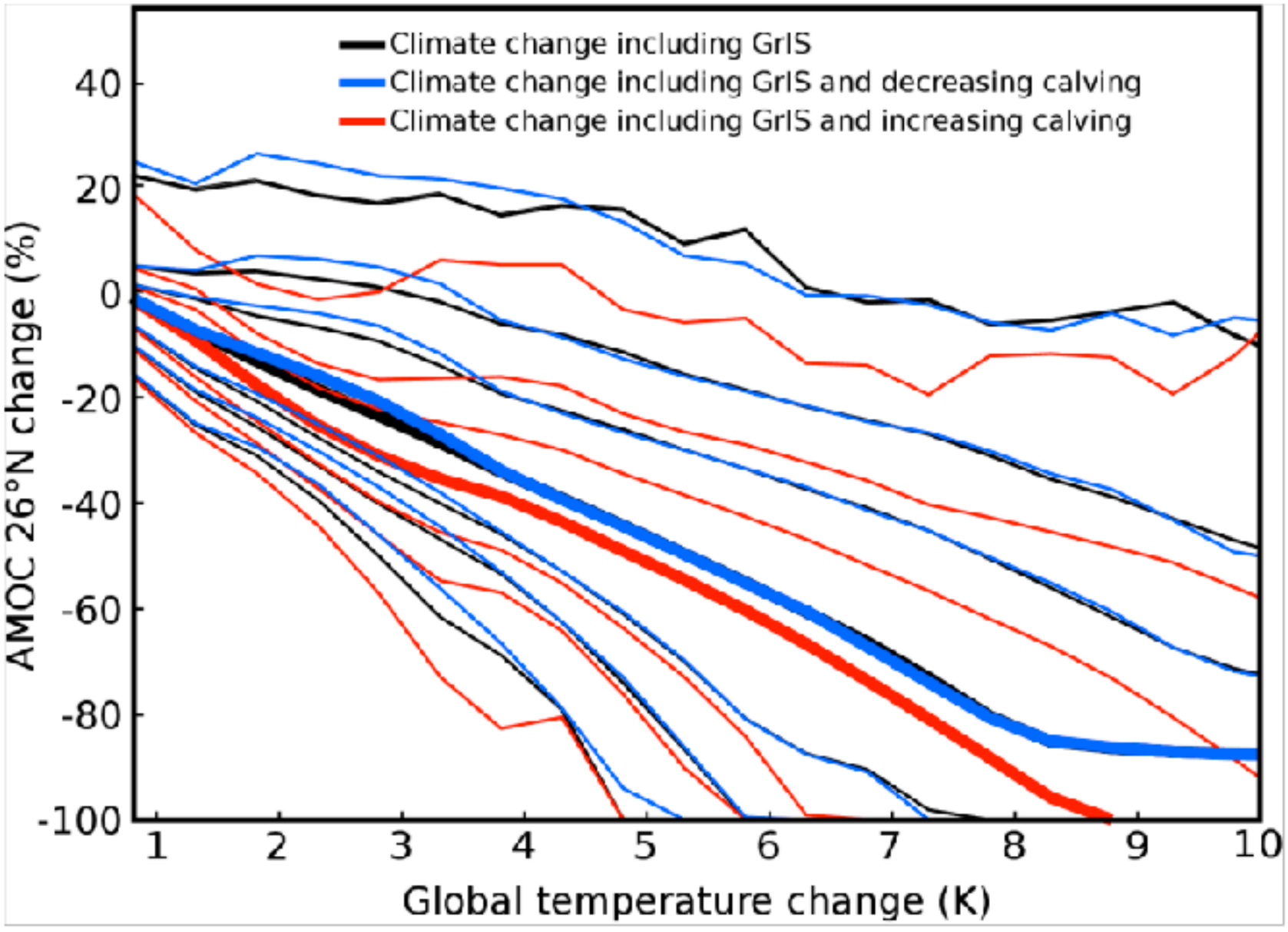
LETTER

doi:10.1038/nature20582

## Centennial-scale Holocene climate variations amplified by Antarctic Ice Sheet discharge

Pepijn Bakker[1]†, Peter U. Clark[1], Nicholas R. Golledge[2,3], Andreas Schmittner[1] & Michael E. Weber[4,5]

# Effects of Calving



| Model name | Historical | RCP4.5 | RCP4.5-gGrISmelt | RCP4.5-rGrISmelt | RCP8.5 | RCP8.5-gGrISmelt | RCP8.5-rGrISmelt | Freshwater forcing method | Ocean Resolution (latitude x longitude x vertical levels) | Atmospheric Resolution (latitude x longitude x vertical levels) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ACCESS1.0 | 2006 | 2300 | | 2300 | 2100 | 2300 | 2300 | Freshwater | 1x1x50levs | 1.875x1.25x38levs | Dix et al., 2013 |
| CanESM2 | 2006 | 2300 | 2300 | 2300 | 2100 | 2195 | 2160 | Negative salt flux | 1.41× 0.94x40levs | T63x35levs | Yang and Saenko, 2012 |
| CCSM4 | 2006 | 2300 | 2250 | 2250 | 2300 | 2300 | 2300 | Negative salt flux | 1.11x0.27-0.54x60 | 0.9×1.25x26levs | Meehl et al., 2012 |
| CESM1.1.2 | 2006 | | | | 2200 | 2200 | | Negative salt flux | 1.11x0.27-0.54x60 | 0.9×1.25x30levs | Meehl et al., 2013 |
| GFDL-ESM2Mb | 2006 | 2100 | 2100 | | 2100 | 2100 | | Freshwater | 1x(1-1/3)x50levs | 2x2.5x24levs | Dunne et al., 2012 |
| IPSL-CM5A-LR | 2006 | 2300 | 2300 | | | | | Freshwater | 2x2x31levs | 1.9x3.75x39levs | Dufresne et al., 2013 |
| MIROC4m | 2006 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | Freshwater | 0.5-1.4x1.4x44levs | T42x20levs | Hasumi and Emori, 2004 |
| OSUVic | 2006 | 2300 | 2300 | 2300 | 2300 | 2300 | | Negative salt flux | 1.8x3.6x19lev | T42x10levs | Schmittner et al., 2011 |